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Form Approved  
OMB No. 0704-0188

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FEB 16 1989

4. PERFORMING ORGANIZATION REPORT NUMBER(S)

D C

5. MONITORING ORGANIZATION REPORT NUMBER(S)

AFOSR-TR-89-0085

6a. NAME OF PERFORMING ORGANIZATION

Clemson University

6b. OFFICE SYMBOL  
(if applicable)

7a. NAME OF MONITORING ORGANIZATION

AFOSR/NE

6c. ADDRESS (City, State, and ZIP Code)

Dept of Mech Engineering  
Clemson, SC 29634-0921

7b. ADDRESS (City, State, and ZIP Code)

Building 410  
Bolling AFB, DC 20332-64488a. NAME OF FUNDING/SPONSORING  
ORGANIZATION

AFOSR

8b. OFFICE SYMBOL  
(if applicable)

NE

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

AFOSR-87-0086

8c. ADDRESS (City, State, and ZIP Code)

Building 410  
Bolling AFB, DC 20337

10. SOURCE OF FUNDING NUMBERS

PROGRAM  
ELEMENT NO.

61102F

PROJECT  
NO.

2917

TASK  
NO.

A3

WORK UNIT  
ACCESSION NO.

11. TITLE (Include Security Classification)

RELATIONSHIP OF PROCESSING TO MICROSTRUCTURE AND MECHANICAL  
PROPERTIES IN METAL MATRIX COMPOSITES

12. PERSONAL AUTHOR(S)

Professor Rack

13a. TYPE OF REPORT

Final

13b. TIME COVERED

FROM 1 Nov 86 TO 31 Oct 88

14. DATE OF REPORT (Year, Month, Day)

15. PAGE COUNT

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Historically, research designed to elucidate the fundamental mechanisms controlling the physical and mechanical response of advanced materials, for example, metal and ceramic matrix composites, has been severely hindered by the investigator's inability to procure experimental materials whose prior thermomechanical history is known and well characterized. Conflicting and apparently irreproducible results could, in many instances, have been directly ascribed to a lack of prior processing information. The laboratory facilities established utilizing equipment procured under the subject grant were designed to minimize this obvious shortcoming. In addition, the equipment purchased has been, and continues to be utilized to support a number of research programs of immediate and potential future DoD interest.

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UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL

Rosenstein

22b. TELEPHONE (Include Area Code)

(302) 717-4453

22c. OFFICE SYMBOL

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**RELATIONSHIP OF PROCESSING TO MICROSTRUCTURE AND MECHANICAL  
PROPERTIES IN METAL MATRIX COMPOSITES**

**FINAL REPORT**

**USAFOSR GRANT NO. AFOSR-87-0086**

**SUBMITTED BY**

**H. J. RACK  
DEPARTMENT OF MECHANICAL ENGINEERING  
CLEMSON UNIVERSITY  
CLEMSON, SOUTH CAROLINA**

**DECEMBER 1, 1988**

## INTRODUCTION

Historically, research designed to elucidate the fundamental mechanisms controlling the physical and mechanical response of advanced materials, for example, metal and ceramic matrix composites, has been severely hindered by the investigator's inability to procure experimental materials whose prior thermomechanical history is known and well characterized. Conflicting, and apparently irreproducible results, can, in many instances have, been directly ascribed to a lack of prior processing information. The laboratory facilities established utilizing equipment procured under the subject grant were designed to minimize this obvious shortcoming. In addition, the equipment purchased has been, and continues to be utilized to support a number of research programs of immediate and potential future DoD interest.

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## EQUIPMENT PROCURED

A listing of the equipment procured utilizing funds provided by the subject equipment grant is given in Table 1. All equipment is currently operational.

Table 1

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RELATIONSHIP OF PROCESSING TO MICROSTRUCTURE AND MECHANICAL PROPERTIES IN METAL MATRIX COMPOSITES

ITEM	VENDOR	EQUIPMENT	AIR FORCE	CLEMSON UNIVERSITY	
				COST SHARE	TOTAL
1	K.H. Huppert	Recirculating Air Furnace	3,296.81	2,675.19	5,972.00
2	Fisher Scientific	Globar	1,563.39		1,563.39
3	W.H. Kay Co	Salt Baths		7,363.58	7,363.58
4	Gatan	Dual Beam Ion Mill		46,598.00	46,598.00
5	Gatan	Automatic Terminator			
6	Gatan	Cold Stage and Dewar			
7	Gatan	Liquid Nitrogen Trap			
8	Gatan	Electronic Gas Flow Control			
9	Gatan	Ultrasonic Disc Cutter			
10	Gatan	Precision Dimple Grinder			
11	E.A. Fischione	Electrothinner		3,740.00	3,740.00
12	Ralnike's	Bench EDM System		6,950.00	6,950.00
13	Perkin Elmer	DSC-4		2,527.29	2,527.29
18	Perkin Elmer	DSC 4 Liquid Nitrogen		3,075.00	3,075.00
19	Omitherm Corp.	High Temp DSC		4,119.41	4,119.41
20	Omitherm Corp.	Software		1,236.90	1,236.90
24	Omega Engr	Lever Arm Creep Test	27,150.00		27,150.00
	MMI	Lever Arm Creep Test	10,950.00		10,950.00
	Applied Test Systems	Lever Arm Creep Test	14,452.46		14,452.46
	Zenith Data Systems	Lever Arm Creep Test			
	Data Translation	Lever Arm Creep Test			
	Eaton Corporation	Lever Arm Creep Test			
	Jameco Elec	Lever Arm Creep Test			
25	Wall Metallurgical	Machine Weights	2,000.00		2,000.00
26	Wall Metallurgical	Pull Rod	4,656.26		4,656.26
	Applied Test	Pull Rod			
27	Wall Metallurgical	Extensometer	1,200.00		1,200.00
28	Wall Metallurgical	LVDI Transducer	800.00		800.00
30	Therm Craft	Furnaces	9,955.00		9,955.00
	Wall Metallurgical	Furnaces			
	Omega Engr	Furnaces			

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RELATIONSHIP OF PROCESSING TO MICROSTRUCTURE AND MECHANICAL PROPERTIES IN METAL MATRIX COMPOSITES

<u>ITEM</u>	<u>VENDOR</u>	<u>EQUIPMENT</u>	<u>AIR FORCE</u>	<u>CLEMSON UNIVERSITY COST SHARE</u>	<u>TOTAL</u>
32	MTS Systems Wells American	Computer Control	15,133.50		15,133.50
33	MTS Systems Compusult Centorr Assoc. Nicolet Amtek, Inc. Computerland Centorr Assoc. Welders Supply House	High Temp	73,502.48	104,431.29	177,933.77
34		Arc Melter	11,572.06		11,572.06
	Taxes		9,324.42	3,213.92	12,538.34
	Freight		443.62	69.42	513.04
	<b>TOTAL COSTS</b>		186,000.00	186,000.00	372,000.00

## RESEARCH PROGRAMS

The following is a brief summary of the research activities currently being conducted utilizing the equipment procured under the subject grant.

### - High Temperature Plastic Flow and Fracture of Multiphase Alloys and Composites

This research effort funded as a sub-contract from Carnegie-Mellon University as part of the AFOSR University Research Initiative "High Temperature Metal Matrix Composites" is examining the high temperature plastic flow and fracture behavior of both multi-phase intermetallic alloys (TiAl, Ti<sub>3</sub>Al) and discontinuously reinforced metal matrix composites (TiB<sub>2</sub> reinforced TiAl, TiC reinforced INCONEL 718) utilizing the high temperature creep and closed-loop MTS systems. Future plans include extending these studies to higher temperature intermetallic (Nb) and ceramic alloys and composites utilizing the unique high temperature (2000°C), environmental and mechanical stability of the closed-loop MTS system.

### - High Temperature Fatigue Crack Growth Behavior of Ti<sub>3</sub>Al Based Intermetallic Alloys

This effort is being funded as a sub-contract from Garrett Engine to AFWAL and will examine the environmental crack growth behavior of a series of Ti<sub>3</sub>Al based intermetallic alloys. Environments of interest will include vacuum, inert atmosphere, air and low pressure H<sub>2</sub> utilizing the closed-loop MTS system.

- High Temperature Creep Behavior of Whisker Reinforced Al Metal Matrix Composites

The effects of whisker orientation and matrix heat treatment on the creep behavior of SiC whisker reinforced 2124 aluminum are being examined utilizing the creep facility established under the grant. This study is being complimented by an investigation of a sol-gel methodology recently developed under AFOSR funding at Clemson for altering the interfacial bonding characteristics of both discontinuous and continuous reinforcements.

- Precipitation Strengthening of Whisker Reinforced Al, Mg and Ni Matrix Metal Matrix Composites

Aging behavior is being examined in a series of Al (Al-Mg-Cu, Al-Mg-Cu-Li), Mg (Mg-6Zn) and Ni (INCONEL) matrix composites. These studies, funded by NASA-Langley (Al) and AFOSR (Ni), involve detailed transmission electron microscopy, and utilize the heat treatment, thermal analysis and foil preparation equipment procured under the subject grant.

- Interfacial Reactions in Continuously Reinforced Metal Matrix Composites

Interfacial reactions and the modification of interfaces, thru sol-gel processing, is being examined in continuous C reinforced composites. Sample preparation and examination utilize subject grant equipment.